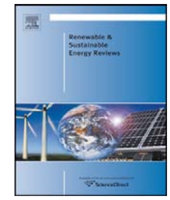
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An analysis of Turkish hydropower policy

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ABSTRACT

Over the last decade, Turkish electricity demand has increased more than 8% per annum as a result of economic development. Being one of the renewable energy sources par excellence, non-exhaustible, non-polluting and economically more attractive than other renewable sources, hydropower has turned out to be an important contributor to the future energy mix of the country. This paper deals with hydropower policies to meet increasing electricity demand for sustainable energy development in Turkey. Turkey has a total gross hydropower potential of 433 TWh/year and 140 TWh/year of this capacity can be used economically, corresponding to the second largest economic potential in Europe. Currently only 35% of economic hydro potential of the country is utilized. After completion of hydropower plants under construction, this figure will increase to 49%. It is obvious that even after the construction of all projects there will still be a huge hydro potential in Turkey. Besides, Turkey is a poor country in terms of fossil fuels (oil, natural gas, coal and so on) and has no nuclear power plant in operation, which strengthens the role of hydro energy among other alternatives.

Contents

1. Introduction

Approximately 70% of the Earth's surface is covered with water, a resource that has been exploited for many centuries. Actually, water manipulation dates from the dawn of civilization. Mesopotamians built dams and irrigation canals at least 8000 years ago and town water supply systems operated from 3000 BC in Jordan. Ancient water systems and dams have been found in Asia and South America. Humans began to capture energy from flowing water using wheels with buckets to lift water in ancient Egypt and Sumeria. In 1832, Benoit Fourneyron had developed a water turbine to capture the potential energy of falling water, far more useful than flow-dependent waterwheels. Then, modern dams began to spread to the developing world [1].

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Table 1
Hydropower output in 2007 (GWh).

Country	Hydropower production (GWh)	%
China	485,264	15.8
Brazil	374,015	12.1
Canada	368,407	12.0
United States	249,619	8.1
Russia	177,048	5.8
Norway	133,934	4.4
India	123,812	4.0
Venezuela	83,059	2.7
Japan	74,009	2.4
Sweden	66,160	2.1
France	58,187	1.9
Paraguay	53,725	1.7
Colombia	44,445	1.4
Austria	35,993	1.2
Turkey	35,851	1.2
Switzerland	35,250	1.1
Italy	32,816	1.1
Argentina	30,514	1.0
Vietnam	29,883	1.0
Pakistan	28,707	0.9
Other countries	557,724	18.1
World total	3,078,422	100

Hydro energy is obtained by allowing water to fall on a turbine to turn a shaft. Electricity is produced from the kinetic energy of falling water. The water in rivers and streams can be captured and turned into hydroelectric power, also called hydropower. Hydropower is inexpensive, and like many other renewable energy sources (RES), it does not produce air pollution.

Hydropower is also certainly the largest and most mature application of renewable technologies. In 2007, it was worldwide responsible for 3078 terawatt-hours (TWh) of electricity output, which means about 15.5% of the world's entire electricity demand came from hydropower installations. Hydropower is critically important for many countries; it produces more than 50% of electricity for more than 60 countries. In 2007, the largest hydropower generating countries were China (485 TWh), Brazil (374 TWh) and Canada (368 TWh). Other big hydropower producers are United States, Russia and Norway. Table 1 provides worldwide hydropower output in 2007 by countries [2].

Table 2
Hydropower potential (GWh/year).

	Gross potential	Technical potential	Economic potential
World	40,150,000	14,060,000	8,905,000
Europe	3,150,000	1,225,000	1,000,000
Turkey	433,000	216,000	140,000

Turkey has a gross annual hydro potential of 433 TWh, corresponding to 13.7% of the total hydropower capacity in Europe (see Table 2). Almost half of the gross potential is technically exploitable and 32.3% (140 TWh/year) is economically usable. Currently, 25.6% (35.8 TWh) of this economically-feasible hydropower energy potential is being generated annually by 172 hydroelectric power plants with a total installed capacity of 13,700 MW. Current hydropower generation capacity accounts for 32.8% of the nation's total installed capacity [3].

The focus of this article is on the analysis of Turkish hydropower utilization and policy. The paper is organized as follows. Section 2 provides an overview of current energy profile of Turkey. Section 3 focuses on hydropower utilization in Turkey. A brief account of economics of hydropower is presented in Section 4, followed by Section 5 on advantages and disadvantages of hydropower development. Section 6 evaluates Turkish hydropower policy so far. Section 7 concludes with some policy suggestions.

2. Current energy profile of Turkey

Similar to balance sheet of a company, every country has an energy balance table that reflects its current energy profile.

Table 3
Energy balance table of Turkey in 2007 (ktoe).

	Coal	Crude Oil	Petroleum	Natural gas	Hydro	Geothermal	Solar & wind & other	Waste	Electricity	Heat	Total
Production	14793.7	2108.6	0.0	735.0	3083.2	1047.6	450.4	5054.8	0.0	0.0	27273.3
Imports	14639.8	23279.1	14342.5	29784.2	0.0	0.0	0.0	0.0	74.3	0.0	82119.9
Exports	0.0	0.0	−6093.9	−25.5	0.0	0.0	0.0	0.0	−208.3	0.0	−6327.7
International bunkers	0.0	0.0	−1984.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−1984.1
Stock changes	−48.5	89.8	−1039.1	−78.6	0.0	0.0	0.0	0.0	0.0	0.0	−1076.3
Total primary energy supply	29385.1	25477.6	5225.4	30415.1	3083.2	1047.6	450.4	5054.8	−134.0	0.0	100005.0
Statistical differences	6.9	115.5	−14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.1
Electricity plants	−12338.8	0.0	−987.4	−13073.2	−3004.6	−133.9	−30.4	−7.9	14937.0	0.0	−14639.2
Autoproducer electricity plants	−780.3	0.0	−164.3	−857.5	−78.6	0.0	−0.2	−42.9	778.5	0.0	−1145.2
CHP plants	0.0	0.0	−1.1	−931.3	0.0	0.0	0.0	0.0	219.0	570.9	−142.4
Autoproducer CHP plants	−182.6	0.0	−262.7	−944.2	0.0	0.0	0.0	−7.2	539.5	461.0	−396.3
Petroleum refineries	0.0	−25650.9	25704.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.3
Coal transformation	−1787.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−1787.7
Non-specified (transformation)	0.0	57.9	−59.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−2.0
Own use	−303.1	0.0	−1492.0	−534.8	0.0	0.0	0.0	0.0	−908.3	0.0	−3238.3
Distribution losses	−20.6	0.0	0.0	−20.7	0.0	0.0	0.0	0.0	−2291.6	0.0	−2333.0
Total final consumption	13978.8	0.0	27948.0	14053.3	0.0	913.6	419.8	4996.8	13140.0	1031.9	76482.2
Industry sector	11228.9	0.0	1418.7	3716.5	0.0	0.0	125.9	0.0	6144.7	1031.9	23666.7
Transport sector	0.0	0.0	15692.2	167.0	0.0	0.0	0.0	12.4	80.4	0.0	15952.0
Residential	2749.8	0.0	1745.1	6901.0	0.0	913.6	293.9	4984.4	3137.0	0.0	20724.9
Commerce and public services	0.0	0.0	0.0	3066.1	0.0	0.0	0.0	0.0	3349.5	0.0	6415.6
Agriculture/forestry/fishing	0.0	0.0	3457.4	0.0	0.0	0.0	0.0	0.0	428.4	0.0	3885.8
Non-energy use	0.0	0.0	5634.5	202.7	0.0	0.0	0.0	0.0	0.0	0.0	5837.2
Electricity output in GWh	53431.0	0.0	6526.0	95025.0	35851.0	156.0	355.0	214.0	0.0	0.0	191558.0

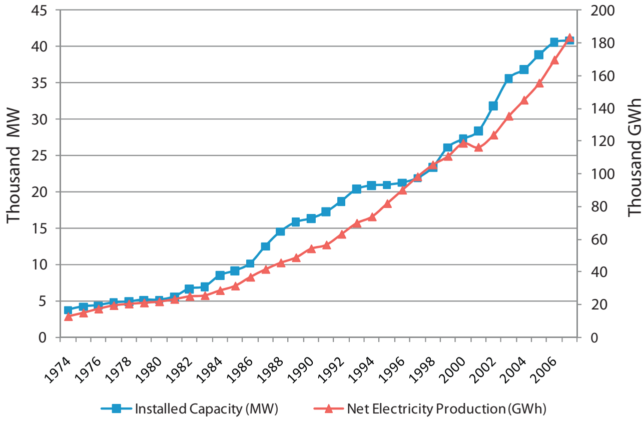


Fig. 1. Installed capacity and electricity output since 1974.

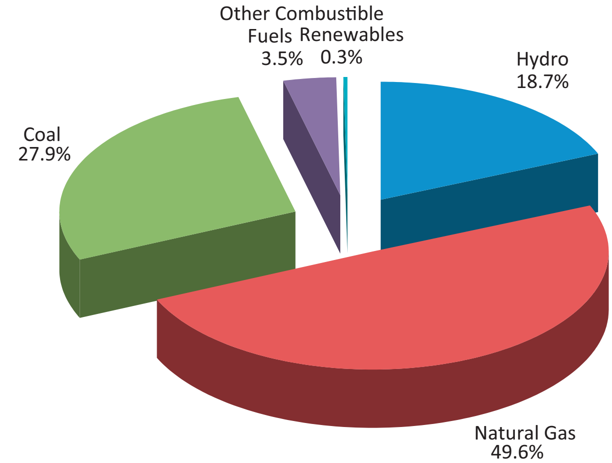


Fig. 3. Electricity output in 2007 (by fuel).

Turkey's energy balance table for 2007 is provided in Table 3 [4]. As can be seen in the table, Turkey's main energy sources are coal, oil, natural gas, hydropower, geothermal, solar, wind and waste. In 2007, primary energy production and final consumption has reached 100 million tonnes (Mt) of oil equivalent (Mtoe) and 76.5 Mtoe, respectively. Fossil fuels provided about 90.5% of the total primary energy production, with oil (30.7%) in first place, followed by coal (29.4%) and natural gas (30.4%). The Turkish coal sector, which includes hard coal as well as lignite, accounts for more than half (54.2%) of the country's total primary energy production, with lignite being the main domestic energy source. The renewables collectively provided 9.6% of the primary energy, mostly in the form of waste (5.1%), hydropower (about 3.1%), geothermal (1.0%), and much less by other renewable energy resources (approximately 0.5%).

Turkey has not utilized nuclear energy yet. Tenders to build nuclear power plants were cancelled several times because of resistance by environmentalists and potentially high investment and operating costs. The current government plans to have a nuclear power plant with a capacity of 1800 MW at the Black Sea port of Sinop. The plant is scheduled to become operational in 2014, but the project is highly controversial. The government's initial plan was to construct three plants with a total capacity of 5000 MW but this had to be scaled back.

In 2007, Turkey had 40,835 MW of electricity generating capacity. An historical summary of installed capacity and electricity generation in Turkey is shown in Fig. 1. As can be seen in the graph, electricity generation in Turkey has more than quadrupled over the last two decades. In 2007, total net electricity production of Turkey has reached about 183.3 terawatt-hours (TWh), 81% of this is produced from thermal power plants, 18.7% from hydropower plants and the remainder 0.3% from other renewable sources. Turkish electricity generation is mainly derived from natural gas, hydro and coal sources (see Figs. 2 and 3). Electricity demand in Turkey is growing rapidly, with an increase rate of 7.8% on average for the last three decades [2]. According to official electricity demand projections given in Fig. 4, Turkey needs to almost double its electricity output, to around 350 TWh, by 2018 [5].

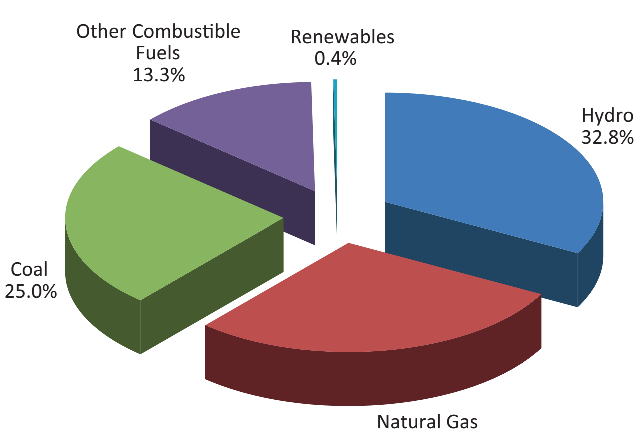


Fig. 2. Installed capacity in 2007 (by fuel).

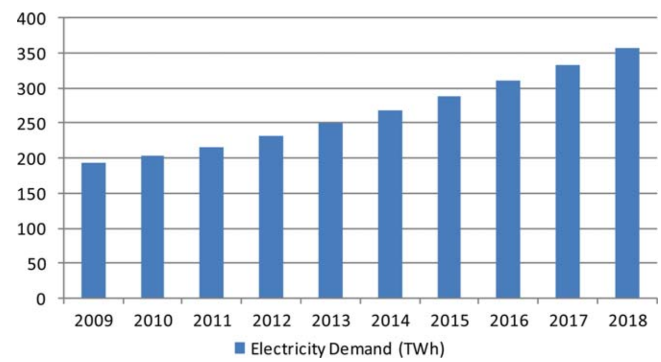


Fig. 4. Development of electricity demand in Turkey.

3. Hydropower in Turkey

The gross and technical hydropower potential of Turkey are estimated at 433 and 216 TWh/year, respectively. The economic potentials for installed hydropower capacity and electricity output have been anticipated roughly as 45,000 MW and 140 TWh/year, respectively (Tables 2 and 4). The gross hydroelectric potential of Turkey is about 1% of the world total and about 14% of the European total [3].

In Turkey, hydro projects were initiated by the Ministry of Public Works in the early 1930s. The Electrical Power Resources Planning and Survey Administration (EIE) was established in 1935 to project Turkey's energy demand, carrying out surveys and studies to develop hydropower potential of the country and other energy resources. However, construction of the dams in real sense started after the end of the World War II except for a few small dams that had been built for irrigation purposes. Since then, the construction of dams and hydropower plants has increased to meet the demand for irrigation and electricity generation. Within 20 years after the establishment of State Hydrologic Works ("DSI" in Turkish initials) in 1954, hydropower production increased to

Table 4
Hydropower plants in Turkey.

Current situation	Number of plants	Installed capacity (MW)	Electricity generation (GWh/year)	%
In operation	172	13,700	48,000	34
DSI	57	10,700		
Others	115	3000		
Under construction	148	8600	20,000	14
DSI	23	3600		
Others	125	5000		
Planned	1418	22,700	72,000	52
DSI	17	4000		
Others	1401	18,700		
Total	1738	45,000	140,000	100

Table 5
Current hydropower plants above 100 MW capacity in Turkey.

No	Name of the plant	Construction started	Construction finished	River	City	Capacity (MW)	Generation (GWh/year)
1	Ataturk	1983	1992	Euphrates	Sanliurfa	2400	8900
2	Karakaya	1976	1987	Euphrates	Diyarbakir	1800	7354
3	Keban	1965	1975	Euphrates	Elazig	1330	6000
4	Altinkaya	1980	1988	Kizilirmak	Samsun	700	1632
5	Birecik (2)	1993	2000	Euphrates	Sanliurfa	672	2518
6	Oymapinar	1977	1984	Manavgat	Antalya	540	1620
7	Berke (2)	1991	2001	Ceyhan	K. Maras	510	1672
8	Hasan Ugurlu	1971	1981	Yesilirmak	Samsun	500	1217
24	Borcka	1999	2007	Coruh	Artvin	300	1039
9	Sir (2)	1987	1991	Ceyhan	K.Maras	284	725
10	Gokcekaya	1967	1972	Sakarya	Eskisehir	278	562
11	Batman	1986	2004	Batman	Batman	198	483
12	Karkamis	1996	1999	Euphrates	Maras	180	652
13	Ozluce	1985	1998	Peri	Bingol	170	413
14	Catalan	1982	1996	Seyhan	Adana	169	596
15	Sariyar (2)	1950	1956	Sakarya	Ankara	160	400
16	Gezende	1979	1990	Ermenek	Icel	159	528
17	Aslantas	1975	1984	Ceyhan	Adana	138	569
18	Hirfanli	1953	1959	Kizilirmak	Kirsehir	128	400
19	Menzelet	1980	1989	Ceyhan	K. Maras	124	515
20	Kilickaya	1980	1989	Kelkit	Sivas	124	332
21	Muratli	1999	2005	Coruh	Artvin	115	444
21	Dicle	1986	1997	Tigris	Diyarbakir	110	298
21	Yamula	1998	2005	Kizilirmak	Kayseri	100	422

3255 GWh, corresponding to 25.3 of total production. Until the early 1990s, hydropower increased its share in total production. However, in the last two decades, the share of hydro plants has decreased as a result of the rapid increase in natural gas plants (from 62% in 1988 to 19% in 2007). Fig. 5 presents the development of hydropower generation in Turkey since 1974 [2].

As of 2009, 172 hydropower plants have been put into operation, 148 are under construction and a further 1418 are at various planning stages (see Table 4). Hydropower plants in operation have an installed capacity of 13,700 MW with an annual average generation of 48,000 GWh. Only 34% of the economically utilizable hydro potential has been developed in Turkey. Besides, 78% of the total hydro capacity in operation has been developed by DSI, corresponding to 10,700 MW (57 hydro plants) of installed capacity. Table 5 lists hydropower plants in operation with a capacity of more than 100 MW in Turkey. As can be seen in Table 5, the most important rivers for hydropower development are Euphrates and Tigris, both of which are trans-boundary rivers originating in Turkey and discharging into the Persian Gulf. Euphrates and Tigris represent over 28% of the country's water supply by rivers and the economically irrigable areas in the region make up 20% of the total in Turkey. In 1977, these two basin projects were given a single title, namely the Southeastern Anatolia Project (GAP in Turkish initials). Thirteen projects were prepared to develop the rich water resources of Euphrates and Tigris for irrigation and power generation. Seven of these projects are in the basin of the Euphrates and six in that of the Tigris. These projects envisage the construction of 22 dams and 19 power plants, generation of 27 TWh of electricity per year over an installed capacity of 7485 megawatts (MW), and irrigation that will cover 1.7 million hectares of land [6].

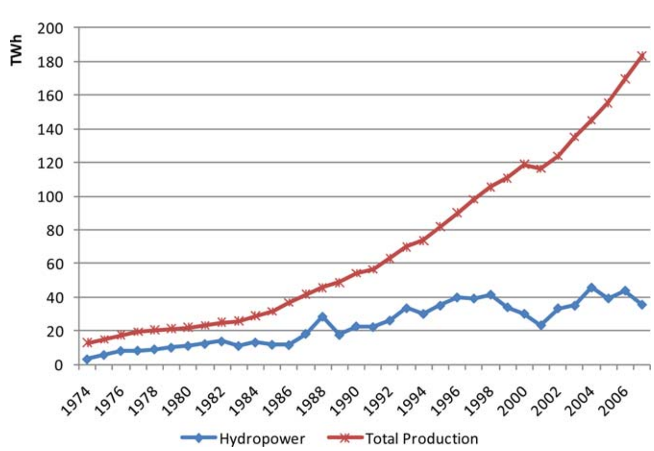


Fig. 5. Hydropower utilization in Turkey since 1974.

4. Economics of hydropower

While renewable energy sources require no fuel and their operation and maintenance costs (O&M) are generally low, the

Table 6
Main characteristics of typical power plants in the Turkish power system in 2006.

	Capacity of plant in general (MW)	Economic life (years)	Capacity utilization rate (%)	Efficiency (%)	Share in total generation (%)	Fuel heat content (kcal/kg)	Fuel cost (€/tonne)	Total capital cost (€/kW)	Total transmission capital costs (€/kW)
Natural gas (CCGT)	600	20	65.0	60.4	40.9	8100	260	720	570
Imported coal	500	20	76.3	41.4	5.5	6000	55	1150	570
Hard coal	300	20	75.3	44.9	1.5	3500	40	1450	570
Lignite	160	20	45.1	34.1	18.1	2470	17	1450	570
Fuel oil (CCGT)	160	20	15.2	48.2	1.4	9860	270	960	570
Hydropower (Dam)	500	20	38.9	–	24.0	–	0	1420	570
Hydropower (River)	10	20	34.1	–	1.1	–	0	1520	0
Bio-CHP	2	20	34.2	–	0.1	–	10	1200	0
Geothermal	15	20	61.6	–	0.1	–	0	1700	0
Wind	1.5	12	24.6	–	0.1	–	0	1120	285
Natural gas (CHP)	40	20	60.5	70.0	4.9	8100	312	864	0
Fuel oil (CHP)	40	20	27.5	70.0	1.2	9860	324	1152	0
Coal (CHP)	40	20	66.0	70.0	1.2	5356	58	1446	0

initial capital costs of renewables are relatively high for per unit of capacity installed. High capital cost is considered to be one of the major barriers to greater use of renewable technologies. Higher generation costs of renewable energy might be attributed to two main aspects. First, renewable energy has higher capital costs than fossil-fuelled systems. Second, external environmental and social costs of fossil fuels have been ignored by markets. These costs include pollution, greenhouse gas emissions, and even military expenditures to defend overseas oil supplies.

Another vital factor in the development and use of hydropower is financing. Much of the cost of generating electricity with oil, coal and gas is the cost of fuel and therefore a thermal investment is made and recouped in relatively short period of time. With renewable technologies, however, the initial capital outlay is large and must be recovered slowly over a period of many years, making it difficult to attract capital. Thus, investment in hydropower is discouraged at the outset.

Like other renewable energy sources, hydropower plants in Turkey are capital intensive but have lower operational costs than thermal options. The high initial cost is a serious barrier for its growth. Table 6 presents a comparison of costs of power plants in Turkey [7]. As seen in table, hydropower is the only renewable source that is capable of providing huge amounts of power in Turkey. In 2006, it alone met 25% of electricity demand while the contribution of all other renewables was less than 1%. Compared to thermal sources, hydropower is also competitive in terms of capital cost and perfectly superior to them in terms of fuel cost, which is zero in hydro plants. Besides, investment and operating cost in Turkey are very low in comparison with many developed countries due to low construction and labor cost.

When considering hydropower development within a country, it is also important to look at its effects in overall economics of the country. It should be noted that hydropower development means that a substantially larger percentage of the capital investment stays within the country as much of the developmental work can be done by local engineers and contractors. The more sophisticated thermal power plants are designed and built by specialized contractors, and this often means that large amounts of capital leave the domestic economy. In many instances, the same is true for the amount of capital necessary for fuel used by thermal power plants. In addition, hydropower facilities require minimal maintenance and do not have the same requirements for skilled personnel as do the more sophisticated thermal power plants.

5. Advantages and disadvantages of hydropower development

As discussed in previous section, the main drawback of hydropower is its initial capital cost. Additionally, dams constructed for hydropower plants raise some social and environmental concerns. The environmental implications are different from fossil fuel cycles. The main implications to be considered with hydroelectricity are the land and water ecosystem impacts associated with construction and operating hydro dams. These concerns include effects of changing river flows on ecosystem regimes, flooding of extensive land areas resulting in relocation of residents and loss of agricultural land, silt deposition and impact on certain sensitive species. Mini hydro and small-scale hydro dams could avert some of social and environmental problems. They could also reduce power shortage vulnerability during drought seasons experienced in large hydro plants. Furthermore, hydropower's fuel sources is renewable, it is available on site (no mining, transporting, etc. required), and no combustion is involved. Hydropower releases no CO_2 directly. It however also has the significant disadvantage that generation depends on rainfall, which varies from year to year.

Unlike fossil fuels, hydro resources are widely spread around the world. Potential exists in about 150 countries, and about 65% of the economically feasible potential remains to be developed (see Tables 1 and 2). Compared to fossil fuels, Turkey is very rich in terms of hydro potential. Besides, hydropower is a proven and well advanced technology with modern power plants providing the most efficient energy conversion process (>90%), which is also an important environmental benefit. Thanks to its fast response time, hydropower plants can be used as peak load. Moreover, it has the lowest operating costs and longest plant life compared with other large scale generating options. Typically a hydro plant may operate up to 40–50 years and this period may be doubled with investment. Moreover, "fuel" of hydropower plants (i.e., water) is renewable, and is not subject to fluctuations in market. Hydro also represents energy independence for many countries.

With growing concern over greenhouse gas emissions and increased demand for electricity, hydropower becomes a key component in energy policies of countries with abundant water sources. Hydropower facilities offer a range of additional benefits. Many dams are used to control flooding, regulate water supply, irrigate land and prevent erosion, and reservoirs provide lakes for recreational purposes.

Actually, in practice, no form of energy production is completely free of effects on the environment. Renewable energy sources have also negative environmental effects even if they are called as green energy. However, these negative effects cannot be compared to those of fossil energy sources. Hydropower plays a major role in reducing greenhouse gas emissions in terms of avoided generation by fossil fuels. Hydro has a relatively small source of atmospheric emissions compared with fossil-fired generating options. Hydropower also avoids the substantial impact

Table 7
The distribution of installed capacity (MW) in Turkey (2008).

	EUAS	Affiliated partnerships of EUAS	Mobile power plants	Production companies & autoproducers & TOOR	Turkey total
Thermal	8690.9	3834.0	262.7	14807.4	27595.0
Hydro	11455.9	0	0	2372.8	13828.7
Geothermal	0	0	0	363.7	363.7
Wind	0	0	0	29.8	29.8
Total	20146.8	3834.0	262.7	17573.7	41817.2

of particulate emissions (e.g., ash). Similarly, hydropower production does not create hazardous or radioactive wastes that require safe long-term storage facilities. Many other environmental impacts associated with the overall fuel cycles of other energy sources are minor or nonexistent for hydroelectric power. These include impacts associated with resource extraction (e.g., coal mining, oil drilling), fuel preparation (e.g., refining), and transportation (e.g., oil spills, other accidents).

Although hydropower development on the global scale seems a relatively clean alternative to power produced through fossil fuels, on the local scale (i.e., the river system) the ecological impacts of hydropower can be significant. The dam and reservoir, which most hydroelectric power facilities require, significantly alter the aquatic habitat and the species present. For instance, a dam may typically hinder migrating fish species in their spawning activities and cause water quality problems.

Table 8
Government support for electricity generation for SHPs in some European countries.

Country	Feed-in tariff (€ cent/kWh)
Belgium	12.5
Germany	7.67 (<500 kW) 6.65 (500 kW to 5 MW)
Greece	6.29
Spain	6.49
France	11.57 (<500 kW) 10.48 (500 kW to 12 MW)
Ireland	6.41
Italy	14.6
Austria	3.15–6.25
Portugal	7.2
Finland	3.02 + subsidy of 30% of investment cost (<1 MW)
Sweden	4.9
UK	2.38 (<20 MW)
Turkey	5.5 (no limitation on installed capacity)

6. Evaluation of Turkish hydropower policy

Approved by parliament in February 2001, the Electricity Market Law brought Turkish legislation in line with that of the EU. As foreseen in the law, an energy watchdog, the Energy Market Regulatory Authority (EMRA), took over responsibility for the electricity market in late 2002. Eventually it is expected to supervise a free market in which private generation companies produce electricity and sell it to private trading companies, large users and distributors under bilateral contracts freely negotiated by the parties. The government meanwhile is supposed to privatize generation assets (including hydro sources) – which account for some 57.3% of total generating capacity (currently owned by public generation company, EUAS) – and make the transmission network available to all market participants (see Table 7) [8]. Distribution is also to be privatized. Households and small commercial users currently purchase their electricity from public distribution company TEDAS (except in three regions where distribution is in the hands of private distribution monopolies). Distribution activities in all regions are envisaged to be operated by private distributors in the future. In preparation for the envisaged open market, the public generation and transmission company, TEAS, has been divided into three companies: EUAS, to manage the generation capacity that remains in public domain; TEIAS, to handle transmission; and TETAS, to carry out electricity wholesale trade until this function is taken over entirely by the market.

Turkey is one of European Union (EU) candidate countries, thus, it is expected that the laws in Turkey have to be compatible to EU regulations and policy. In the context of energy production, EU promotes electricity generation from renewable energy sources. The main instruments for promoting renewables are feed-in tariffs, quota obligations, tenders and (energy) tax exemptions. However, existing Turkish law and regulation with relevance to the use of renewable energy sources is limited to only two pieces of legislation. One piece of legislation is the Electricity Market Licensing Regulation, and the second is the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy (Law Number 5346, dated May 10, 2005). In the regulations, only small hydropower plants (SHPs) are included in the definition of renewable energy resource. Law No. 5346 regards any hydro plant with a reservoir area less than 15 km^2 as renewable energy source and there is no limitation for installed capacities. This causes interest of private sector shift from river-type hydropower plants to large hydropower plants because of potentially higher profit rates. For example, Koprubasi Dam, which is situated on the West Black Sea Basin, having a height of 108 m, a reservoir area of 5.9 km^2 and 79 MW of installed capacity currently lies within the framework of Law No. 5346 [9]. Different definitions create a conflict between Turkey and EU. In European Union, many member states limit the installed capacity of SHPs. Table 8 lists government support for electricity generation for SHPs in some European countries [10].

In Turkey, market based policies for renewables started in 1984 with third-party financing, excise and sales tax exemptions. Capital grants were offered in 2001. The Turkish government's approach to the deployment of renewables reveals its priorities to develop indigenous and renewable resources in conjunction with the expansion of privately owned and operated power generation from renewable sources. The build-own-transfer (BOT) and the build-own-operate (BOO) schemes were put in place in 1984 and financed major power projects (not limited to renewables) with the main objective of attracting private investors. BOT projects were granted a treasury guarantee. Although BOT and BOO approaches attracted significant investment, they also created large public obligations with the government covering the market risk through take-or-pay contracts. The BOT and BOO financing schemes ended in 2000 and were replaced in 2001 by financial incentives within the framework of the Electricity Market Law (Law Number 4628).[2]

According to the Electricity Market Licensing Regulation, promotion of renewable energy sources in the electricity market

[2] Before the Electricity Market Law, the price of energy was decided as a result of negotiations between the energy production companies and the state, which is the buyer. For more information on the subject, see [11] Erdogdu E. Regulatory reform in Turkish energy industry: an analysis. Energy Policy 2007;35:984–93.

has been assigned to the Energy Market Regulatory Authority (EMRA). Specifically, the Regulation states that the issues assigned to the Energy Market Regulatory Authority are "*With regard to the environmental effects of the electricity generation operations, to take necessary measures for encouraging the utilization of renewable and domestic energy resources and to initiate actions with relevant agencies for provision and implementation of incentives in this field*". In this context, there are some incentives and regulations related to renewable energy sources. The incentives brought into existence based on the Electricity Market Licensing Regulation are given below:

- Entities applying for licenses for construction of facilities based on domestic natural resources and renewable energy resources shall pay only 1% of the total licensing fee.
- The generation facilities based on renewable energy resources shall not pay annual license fees for the first 8 years following the facility completion date indicated on their respective licenses.
- Turkish Electricity Transmission Company (TEIAS) and/or distribution companies shall assign priority for system connection of generation facilities based on domestic natural resources and renewable resources.

The aim of the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy is to increase the use of renewable energy sources for generating electricity, as well as to diversify energy resources, reduce greenhouse gas emissions, assess waste products, protect the environment, and develop the necessary manufacturing sector for realizing these objectives. Specific incentives introduced in the law that are applicable to the use of hydropower include [12]:

- *Obligation to purchase electricity from renewable energy sources:* Each legal entity possessing a retail sale license shall be required to purchase renewable energy source-certified (RES-certified) electricity in an amount declared by EMRA.
- *Purchasing of electricity from renewable energy sources with a higher price:* Until the end of 2011, the applicable price for the electricity to be purchased in pursuance with the law within each calendar year shall be the Turkish average wholesale electricity price in the previous year determined by EMRA. However, this price shall be between 5 and 5.5 Eurocent/kWh. The Council of Ministers is entitled to raise this price up to 20% at the beginning of each year.
- *Acquisition of land:* In the case of utilization of property which is under the possession of Forestry or Treasury or under the sovereignty of the State for the purpose of generating electricity from the renewable energy resources included in the law, these territories are permitted on the basis of its sale price, rented, given right of access, or usage permission by the Ministry of Environment and Forestry or the Ministry of Finance. A 50% deduction shall be implemented for permission, rent, right of access, and usage permission in the investment period.

Although Law No. 5346 has some conflicts with EU policy, the effect of the law has been immediately seen after its publication on SHP development resulting in a total of 1024 project applications with an installed capacity of 6500 MW by private sector in Turkey. Furthermore, the publication of this law can be considered as an important step in harmonizing Turkish legislation with that of EU. In addition, Law No. 5784 published in July 2008 allowed legal entities to be exempted from obtaining license to generate electricity from renewable energy up to a capacity of 500 kW. By this law, government also guarantees to buy the excess electricity. It can be expected that this law will also give rise to an increase in installation of mini and micro-hydropower plants in coming years [9].

In order to closely monitor the impact of hydropower plants on natural environment, the owners of hydro plants are required to comply with the requirements of Water Usage Rights Act signed between the company and DSI. According to this act, the facility should maintain a minimum flow (also defined as environmental flow) determined by DSI in the river that is adequate for the existing fish population, wildlife and water quality taking seasonal fluctuations in flow levels into account. However, there is not a standard for the determination of the environmental flow in Turkey. The facility is also required not to contribute to deterioration of water quality either upstream or downstream of the facility. Although construction of fish passages is obligatory in most of European countries, there is no such obligation for SHP projects in Turkey. This may cause loss of fish and/or fish habitat in the project area.

To sum up, currently there is no incentive mechanism in Turkey to support the development of hydropower plants, apart from those having a reservoir area less than 15 km^2. This policy of no-action prevents the development of 50% of Turkey's economically feasible hydro sources and has resulted in a sharp decline in hydropower's contribution to country's overall electricity production from 40% in 1997 to 19% in 2007.

7. Policy suggestions and conclusion

As discussed in previous sections, Turkey has significant hydropower potential making it the second richest country after Norway in Europe. However, currently only 35% of the estimated economical potential is utilized. Hence, there is much to be done for the utilization of remaining hydropower potential. There are still many opportunities in Turkey to develop hydropower plants without any promotion or support. The policy should concentrate on creating confidence among private investors and removing bureaucratic obstacles in front of hydropower investments. Another policy development for Turkey can be the manufacturing of equipment used for hydropower development in domestic market as in the example of China. Government may put into practice some policies to support private sector to produce domestic equipment so that the cost and the time for supplying equipment are reduced.

It seems that the laws on renewable energy utilization for electricity generation in Turkey have brought some improvements to the market. However, they must be revised or redesigned to fulfill the requirements of EU policy as Turkey is a candidate country. Turkish Renewable Energy Law (No. 5346) has connections with EU policy in terms of hydropower development. The most important conflict, however, is mostly resulted from the definition of hydropower as a renewable energy source. The law is applicable to hydropower plants having a reservoir area less than 15 km^2, which may include large dams as a renewable energy source since there is no limitation for installed capacity. This may result in a shift of interest from river-type hydropower plants to large hydropower plants. However, in most European countries, installed capacities of hydropower plants are taken into account for government support. So, current law should be revised and a limitation in terms of installed capacity should be included in the definition of a renewable energy source.

As fossil fuel energy becomes scarcer, Turkey will face energy shortages, significantly increasing energy prices, and energy insecurity within the next few decades. Besides, Turkey's continued reliance on fossil fuel consumption will contribute to accelerating rates of domestic environmental deterioration and global warming. For these reasons, the development and use of

hydro sources and technologies are increasingly becoming vital for sustainable economic development of Turkey.

Turkey is an energy-importing country and meets 82% of its energy needs from foreign sources (see Table 3). In order to be less dependent on other countries, Turkey needs to use its hydro sources. From this point of view, hydropower is an attractive choice since it is economical, sustainable, environmental friendly and a domestic energy source in Turkey. Furthermore, Turkey has several advantages for the use of hydro energy in terms of its location and geographic characteristics. However, today, in Turkey the utilization of hydropower is well below the expected rates mainly due to bureaucratic and economic barriers, insufficient legislative and regulatory framework and poor infrastructure. The private sector, which has the capacity to mobilize needed funds, must be motivated to participate in hydropower development. The process of liberalization, restructuring, and privatization in the Turkish energy sector[3] are also vital; which will assist in creating a favorable environment for investment in hydro energy. Hydro sources in Turkey represent a secure domestic source of energy that is not subject to price fluctuations and supply uncertainties of imported petroleum and natural gas. Future supply of hydropower energy depends on energy prices and technical progress, both of which are driven by energy policy priorities.

Another important barrier preventing widespread use of hydropower in Turkey is the lack of a coherent national energy plan in which the role of hydro sources is explained. Therefore, first of all, Turkey must develop and publicize a rational and coherent energy policy and an action plan; stating short, middle and long term aims, actions and reasons that justify them. Then, the specific place of hydro sources in the overall energy politics of Turkey should be defined. What's more, a kind of effective "High Energy Council" must be set up to provide a higher level of coordination and cooperation within and between institutions, agencies, institutes, and other stakeholders.

On 5 February 2009, Turkish Parliament ratified an agreement to sign the Kyoto Protocol. Actually, signing the Kyoto Protocol does not put an additional burden on Turkey until 2012. Turkey was not a party to the convention adopted in 1992 when the Kyoto Protocol was negotiated, and it is not currently included in the agreement's Annex-B, which includes 39 countries that are obliged to reduce their greenhouse emissions to 1990 levels between 2008 and 2012. However, Turkey will face with an extremely disadvantageous position after 2012 unless it starts to take some measures to reduce its GHG emissions by increasing hydropower utilization.

Finally, although the immediate priority of Turkey should be to speed up the transition process from non-renewable, imported fossil fuels to renewable, domestic energy sources; policy makers should be aware of the fact that even if major efforts were made to develop all domestic sources (especially coal and hydro), they still will not be able to meet the rapidly increasing electricity demand in Turkey in the coming decades. Therefore, policy makers should seriously consider some other alternative energy sources, including nuclear power.[4]

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[3] For more details on the subject, see [11] Ibid.

[4] For more information on nuclear power in Turkey, see [13] Erdogdu E. Nuclear power in open energy markets: a case study of Turkey. Energy Policy 2007;35:3061–73.